Towards coupling coastal ocean models to inland hydrology at NOAA National Ocean Service

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Content

- Coastal ocean modeling framework
- Unified Forecast System
- NOS' Coastal Ocean Models and UFS
- Some of the on-going projects
- Future works

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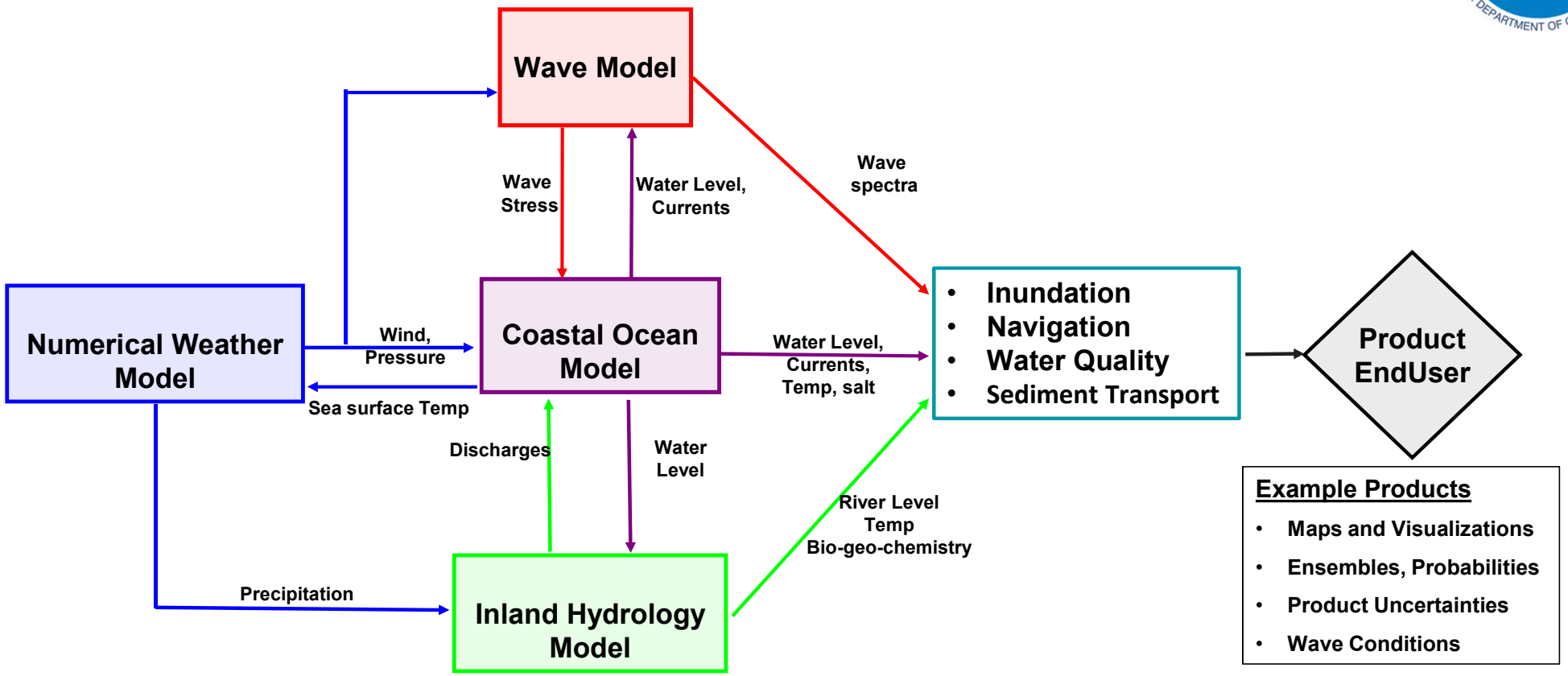
Coastal ocean modeling framework



NOS' Long-Term Strategy

The long-term approach regarding NOS coastal modeling capability is to ***move towards implementing full 3D coastal modeling linked to the inland hydrology models, on a national scale***.

We have identified that ***direct coupling of the coastal circulation model to the inland hydrology model is the long-term approach for NOS'*** national scale coastal circulation models.

Boundary conditions from NOS' operational models are always available to National Water Center or other NOAA partners to support their inland flood modeling efforts.

Unified Forecast System (UFS)

National Unified Operational Prediction Capability (NUOPC) Layer

NUOPC Generic Components	
Driver	Harness that initializes components according to an *Initialization Phase Definition*, and drives their Run() methods according to a customizable run sequence.
Connector	Implements field matching based on standard metadata and executes simple transforms (e.g. grid remapping, redistribution). It can be plugged into a generic Driver component to connect Models and/or Mediators.
Model	Wraps model code so it is suitable to be plugged into a generic Driver component.
Mediator	Wraps custom coupling code (flux calculations, averaging, etc.) so it is suitable to be plugged into a generic Driver component.

NUOPC Layer interoperability rules are implemented using a set of generic components that represent the major structural pieces needed to build coupled models.

Theurich et al. 2016

ESMF/NUOPC enabled models (Selected)

CST	**Coastal ocean**	**ADCRIC, ROMS, FVCOM**
ATM	atmosphere	FV3 (Finite-Volume Cubed-Sphere Dynamical Core), GSM (Global Spectral Model), NMMB (Non-hydrostatic multiscale model on the B-grid) WRF
OCN	ocean	MOM5 and MOM6 (Modular Ocean Model)
WAV	wave	WWIII (WAVEWATCH III)
ICE	sea ice	CICE (Los Alamos Sea Ice Model), KISS (Keeping Ice's Simplicity)
HYD	hydrology	WRF-Hydro (Weather Research and Forecast Model Hydrology), NWM
LND	land	LIS (Land Information System)

Validating	In development	Plan to develop

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NOAA National Ocean Service

NEMS (NUOPC/ESMF) Applications

Application	ATM	OCN	WAV	ICE	HYD	LND	AER	IPM	CST
COASTAL Act	HWRF (data)		WWIII		NWM				ADCIRC
NWI-ROMS			WWIII		NWM				ROMS
NWI-FVCOM			WWIII		NWM				FVCOM
OTT-ROMS	WRF								ROMS
OTT-Alaska		RTOFS (data)	WWIII	CICE					ADCIRC

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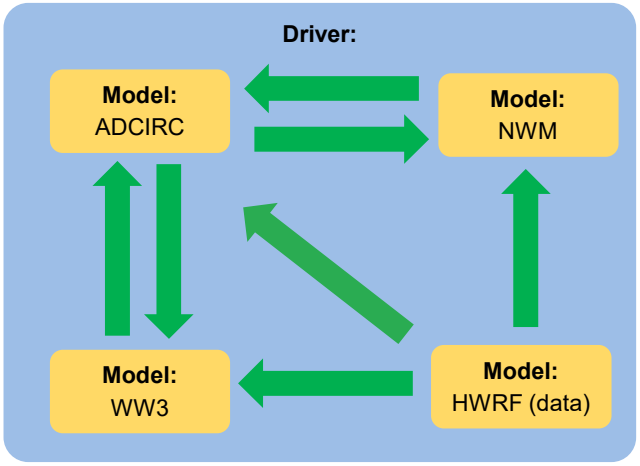
COASTAL Act application

NOAA's Environmental Modeling System (NEMS)



NUOPC components

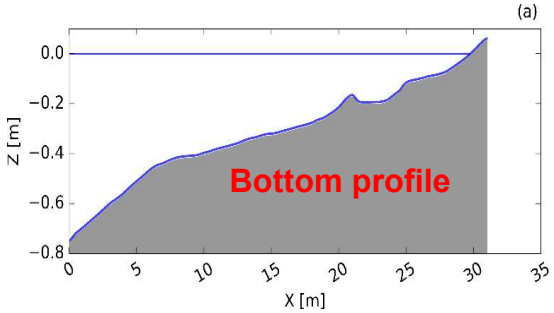
NOAA Technical Memorandum NOS CS 41

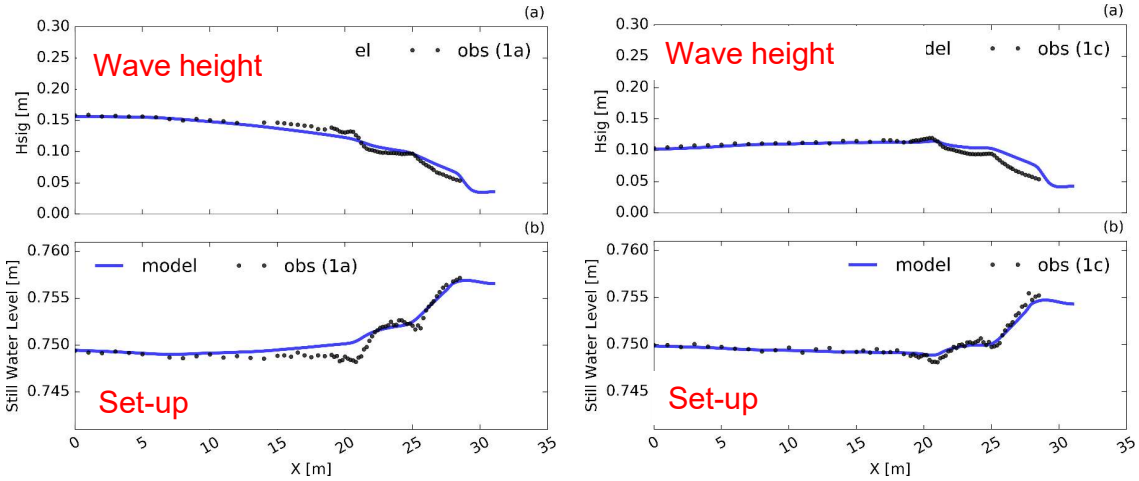
DEVELOPMENT OF A FLEXIBLE COUPLING INTERFACE FOR ADCIRC MODEL FOR COASTAL INUNDATION STUDIES

Moghimi et al, 2019;

WaveWatch III and ADCIRC sub-system validation

Boer, 1996 wave flume test case





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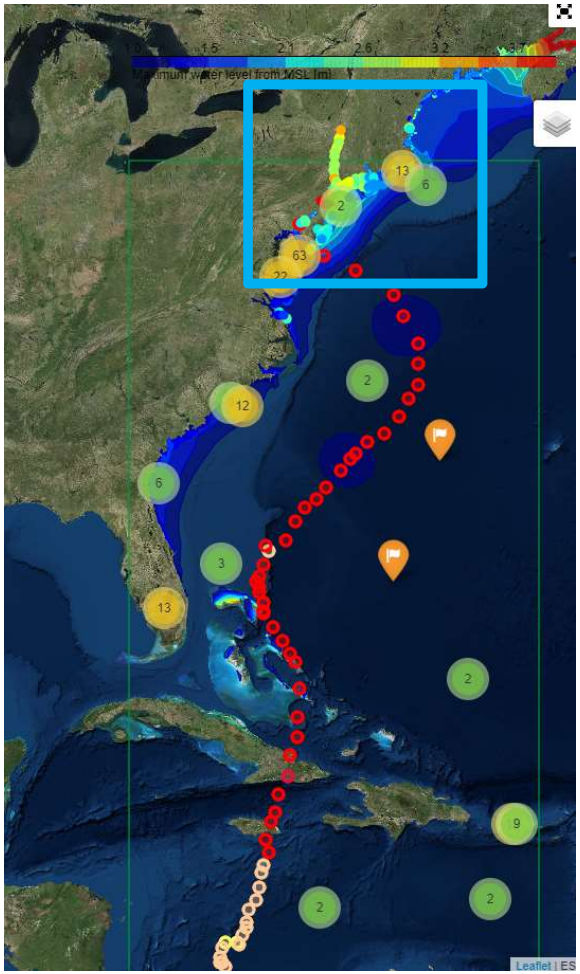
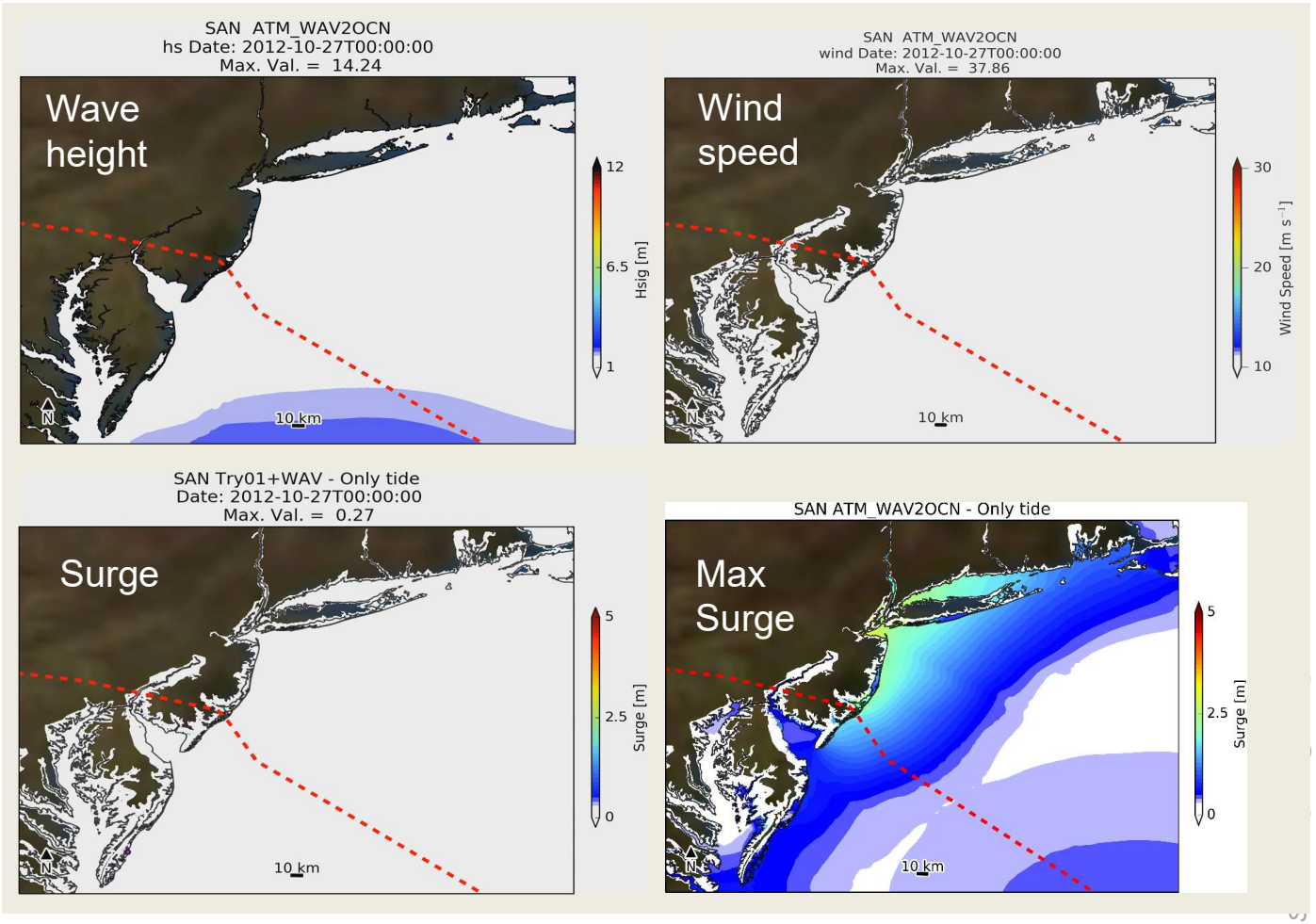
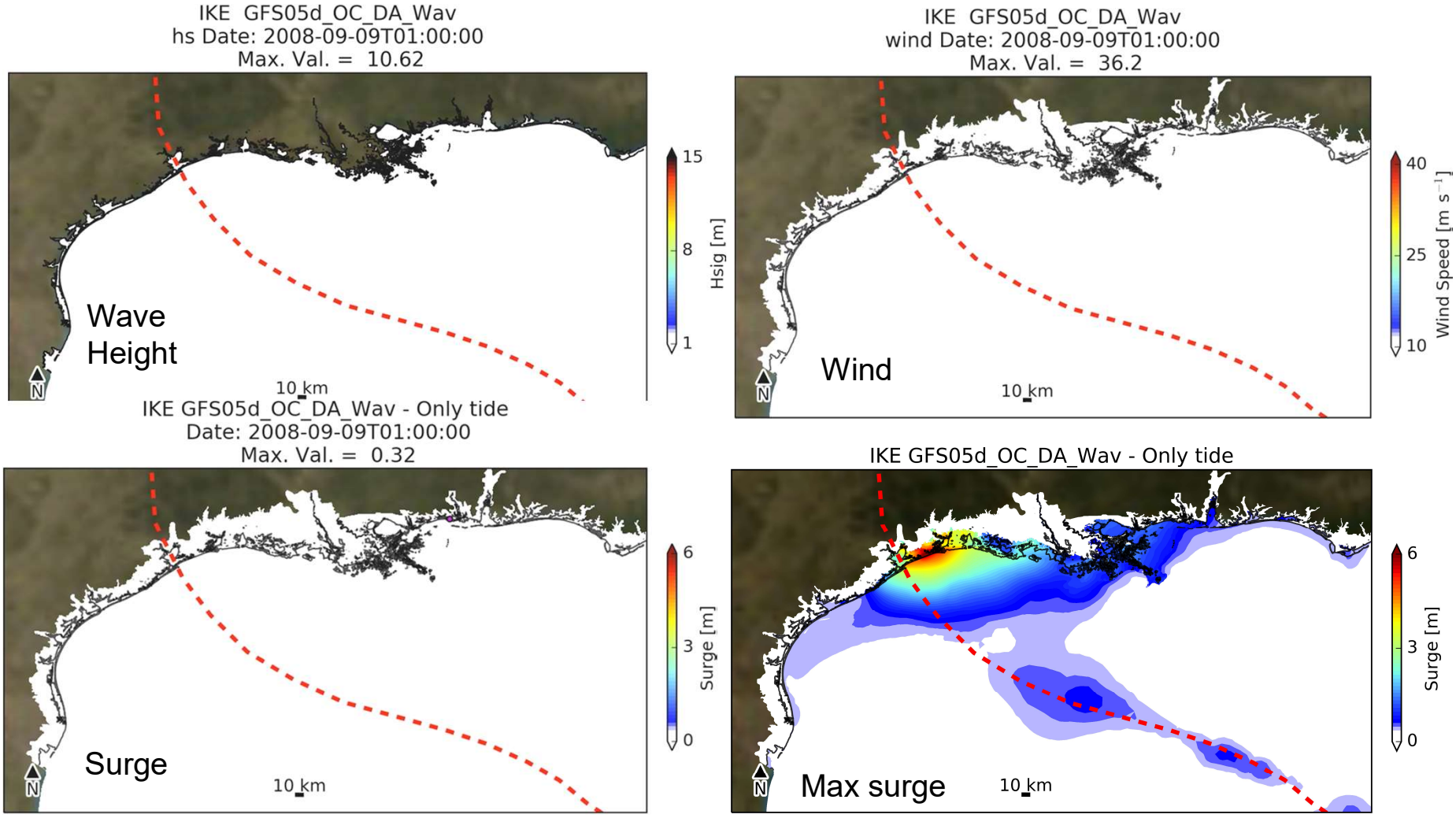
HWRF+WW3 to ADCIRC for Sandy, 2012





HWRF+WW3+ADCIRC for Ike, 2008



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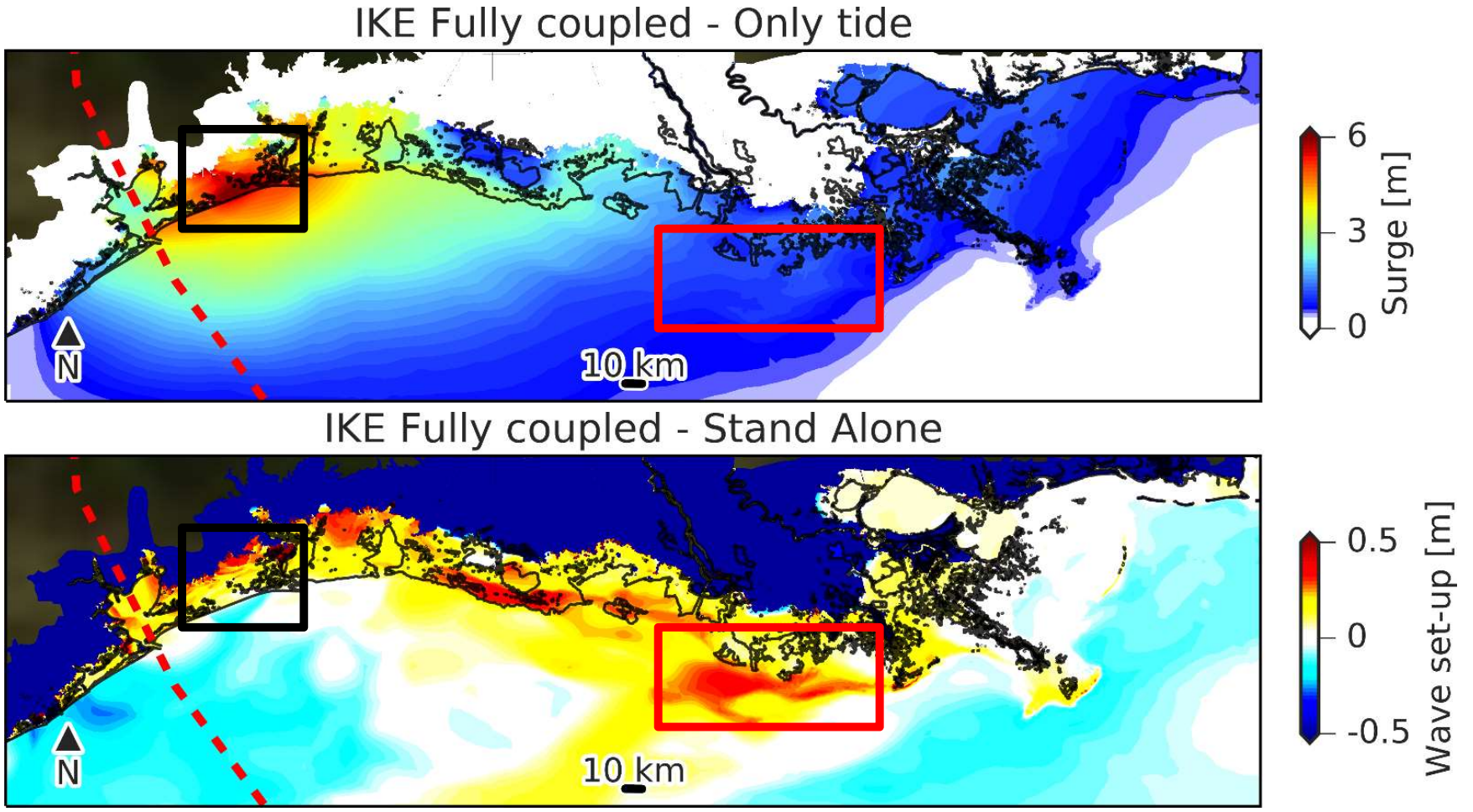
HWRF+WW3 to ADCIRC for Ike, 2008



Dynamical effects on maximum water level

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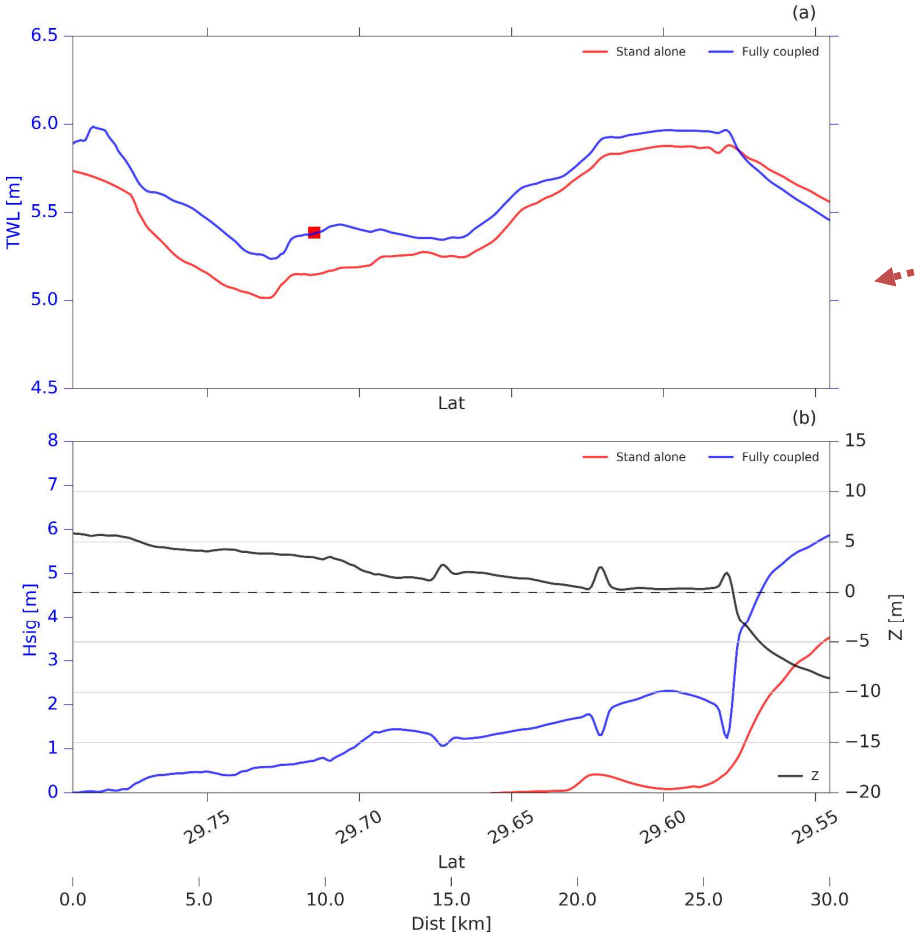
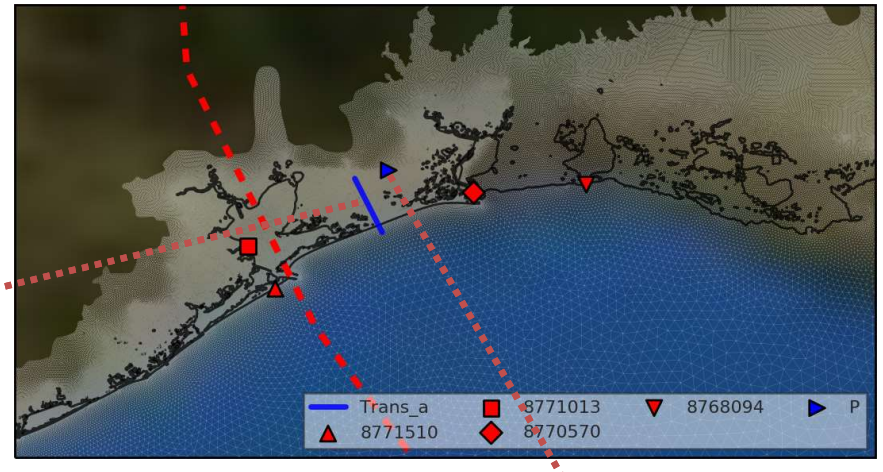
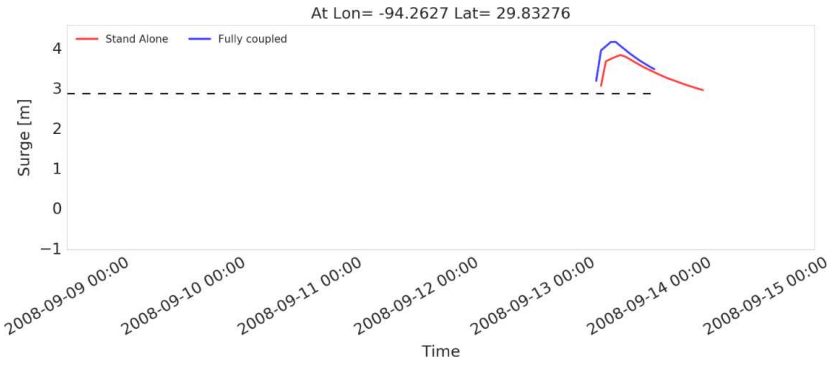
HWRF+WW3 to ADCIRC for Ike, 2008

Trans A: maximum water level and wave height





Total water level



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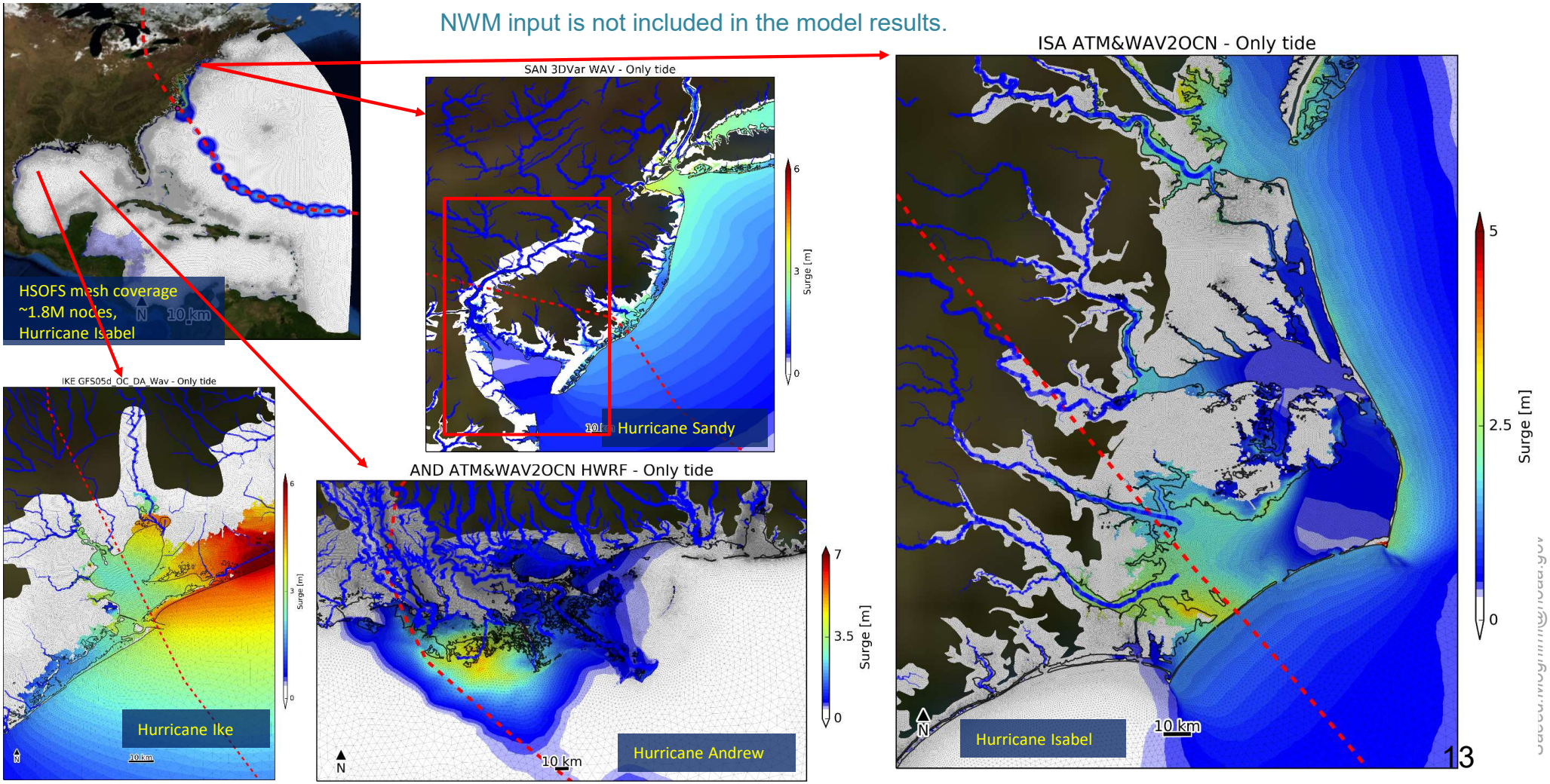
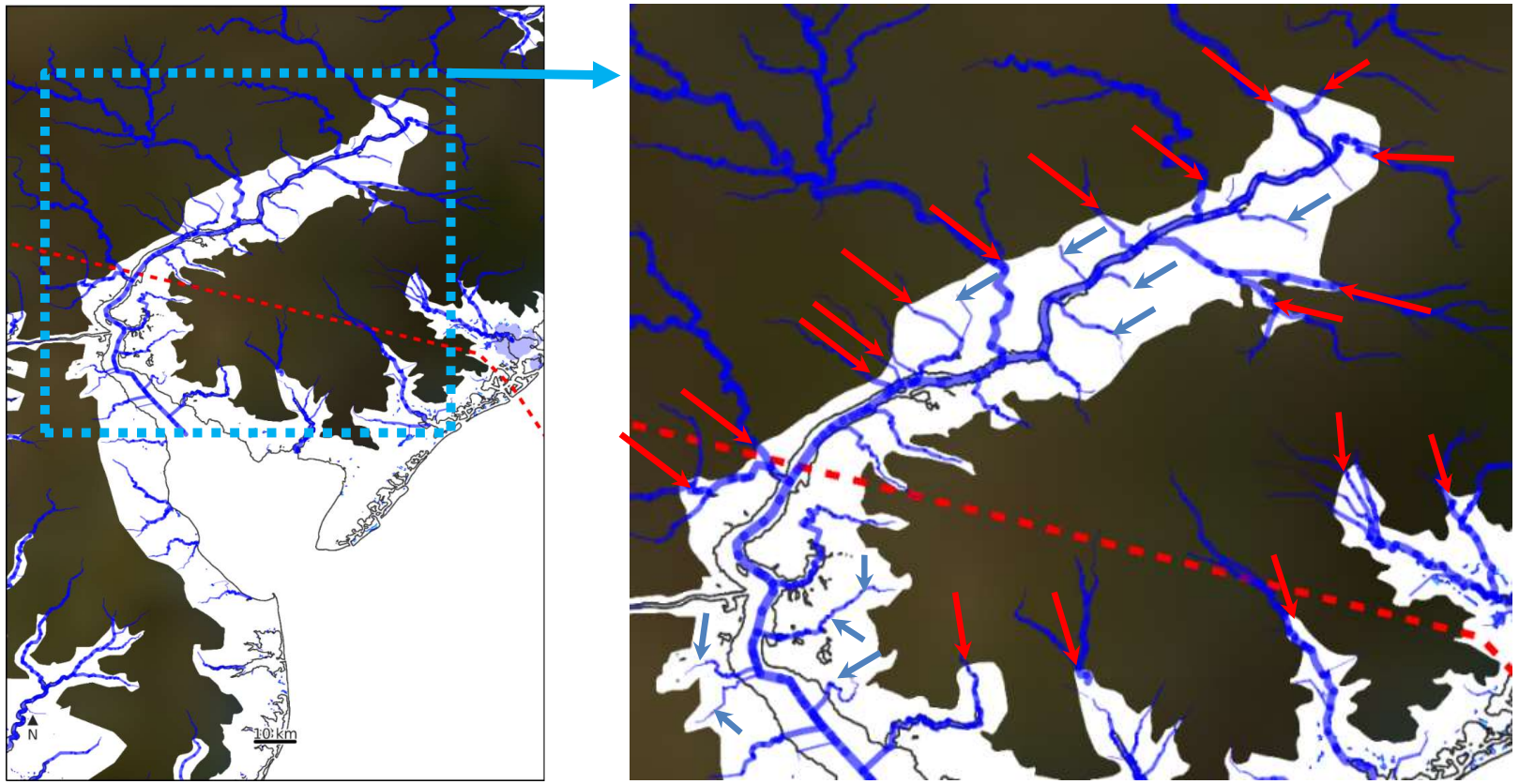
Comparing ADCIRC and NWM (inland hydrology) coverage



Inland hydrology and coastal ocean models coupling



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Exploring Creek-to-Ocean 3D modeling SCHISM and NWM

In collaboration with:
Virginia Institute of Marine Science

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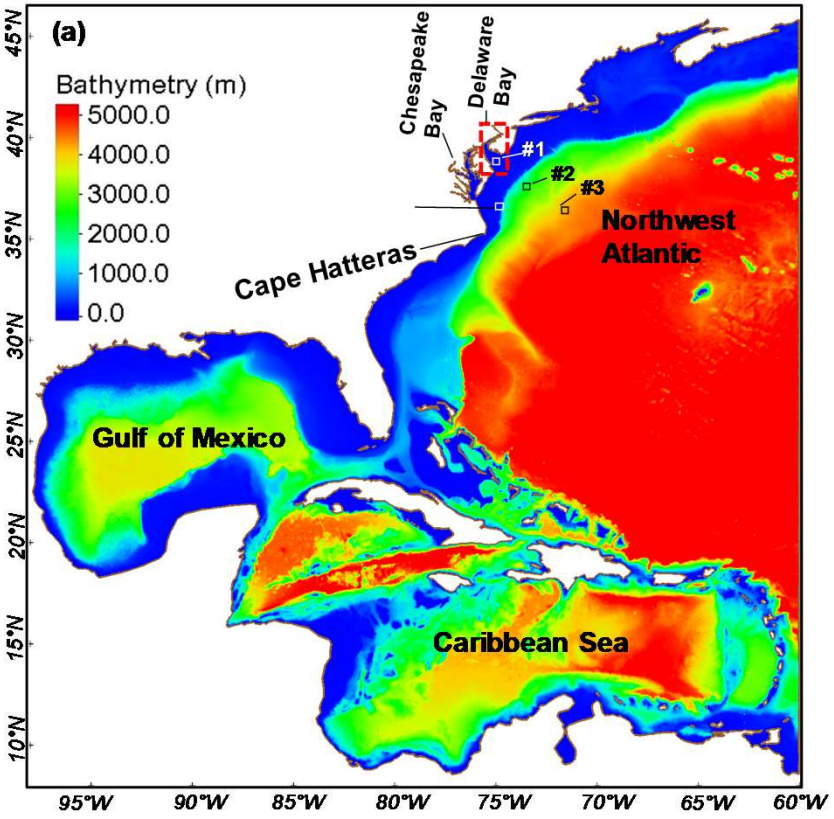
SCHISM model domain



- *Un-smoothed bathymetry*
- *USGS high-resolution DEM (NAVD88) (flat datum)*
- *Explicitly representing NWM segments in the horizontal mesh: 759K nodes and 1,478K elements*
- *Grid resolution: 2~7 km in the ocean; 50-200 m in the main channel of DB; down to ~20m in small streams*
- *Terrain following vertical mesh with varying number of layers (LSC^2)*
- *3rd order transport scheme based on WENO*
- *Ocean boundary forced by HYCOM*
- *Hot start from HYCOM (with approximated salinity/temperature field inside the Delaware Bay)*
- *Atmospheric forcing from ECMWF (ERA)*
- *freshwater inflow inside Delaware Bay from NWM*

- *Simulation period: 2011-7-27 ~ 2011-9-10 (50 days)*
- *Time step: 150 seconds*
- *Baseline (3D baroclinic): 80x Real Time on 1440 cores of Pleiades (NASA)*
- *The 2D model runs approximately 57 times faster than the baseline and can be efficiently conducted using as few as 40 cores.*

- ❑ Use a large domain for storm surge
- ❑ Resolve Gulf Stream to get baroclinic response right during storms
- ❑ Coupled with National Water Model (NWM) at 10 m above MSL
- ❑ Seamless creek-to-ocean capability

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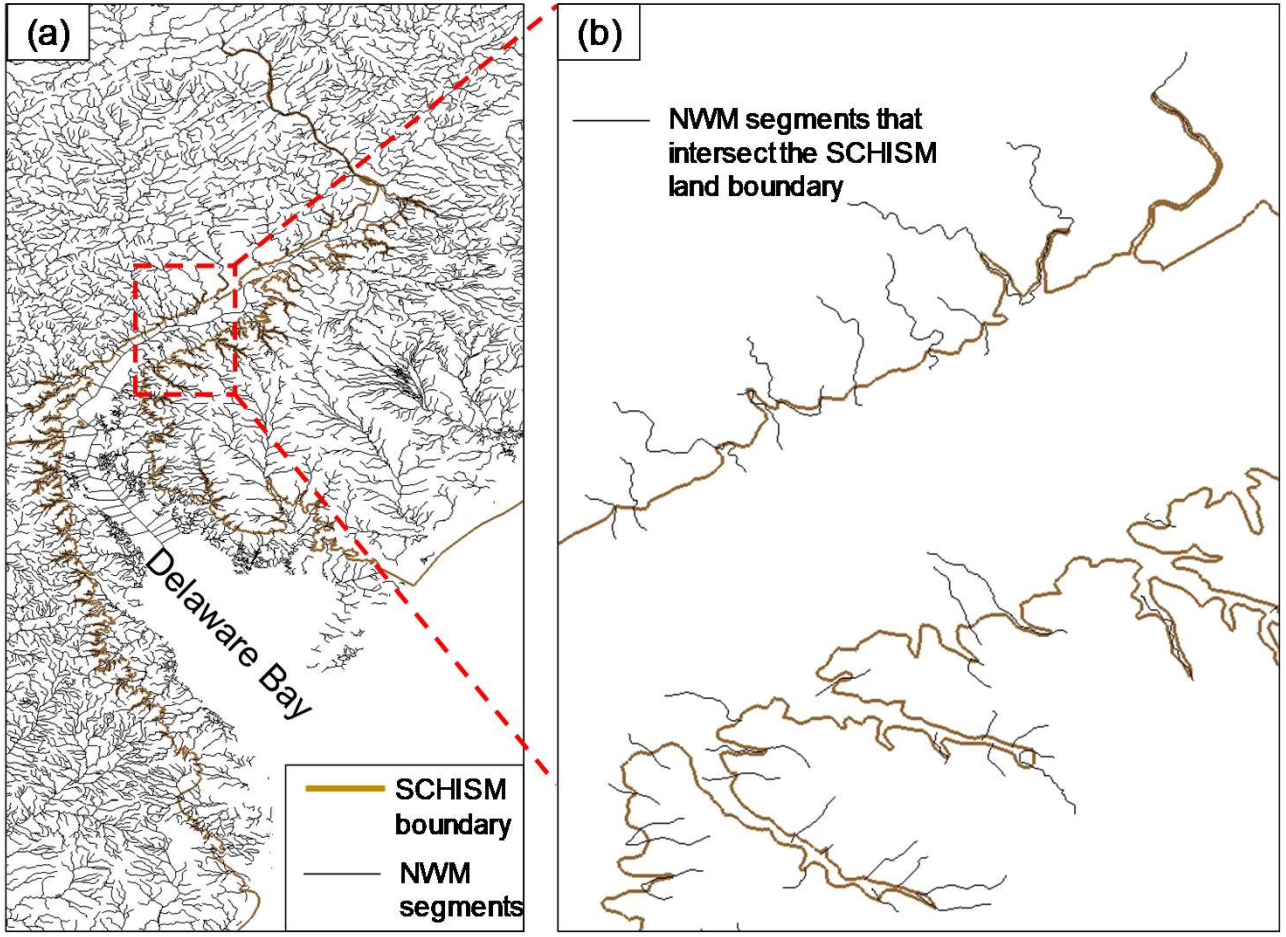
Coupling to NWM



- The intersection points between NWM Segments and the SCHISM land boundary are determined.
- NWM flows are directly imposed based on the streamflow of the intersecting segments
- One-way coupling at the moment, from NWM to SCHISM

Ye et al, in press; Ocean Modelling

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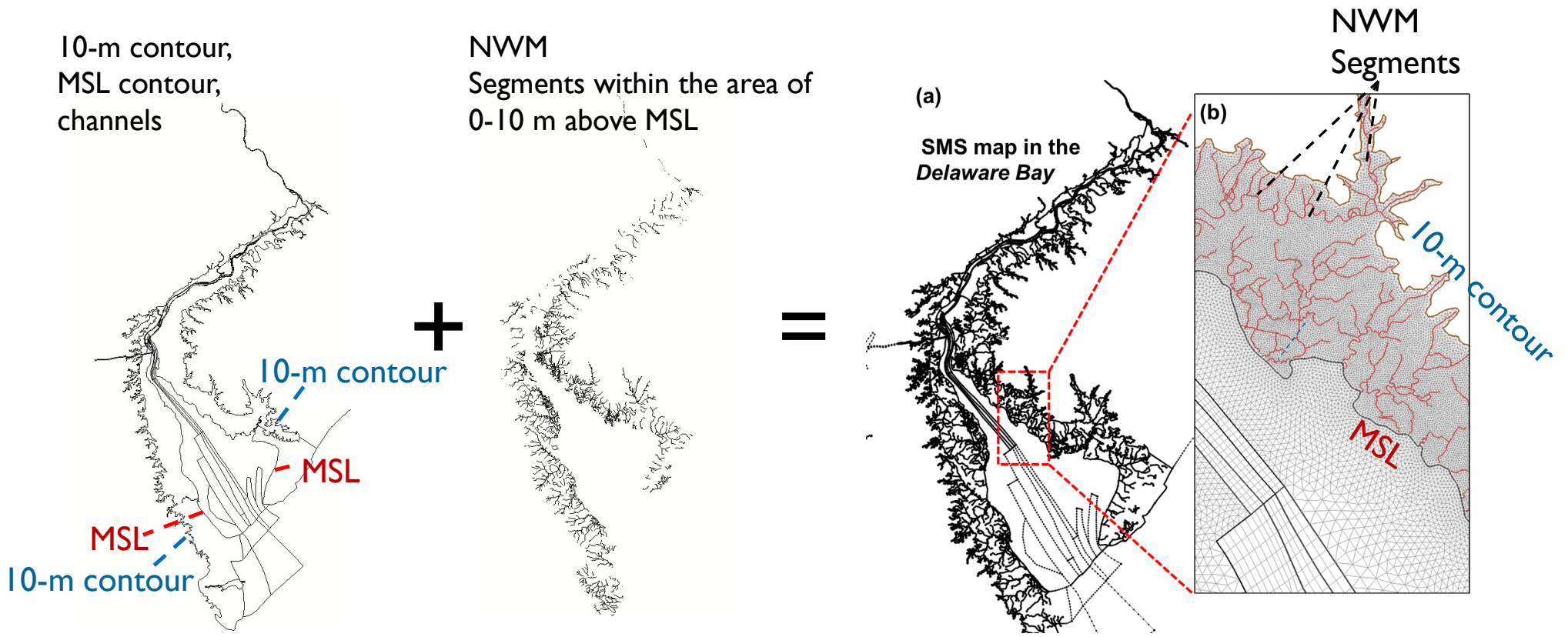
Mesh Generation for DE Bay

- The ocean model mesh overlaps with NWM's coverage of streams
- NWM streams are explicitly represented in the SCHISM mesh
- The pluvial processes below the 10-m contour are directly handled by SCHISM.



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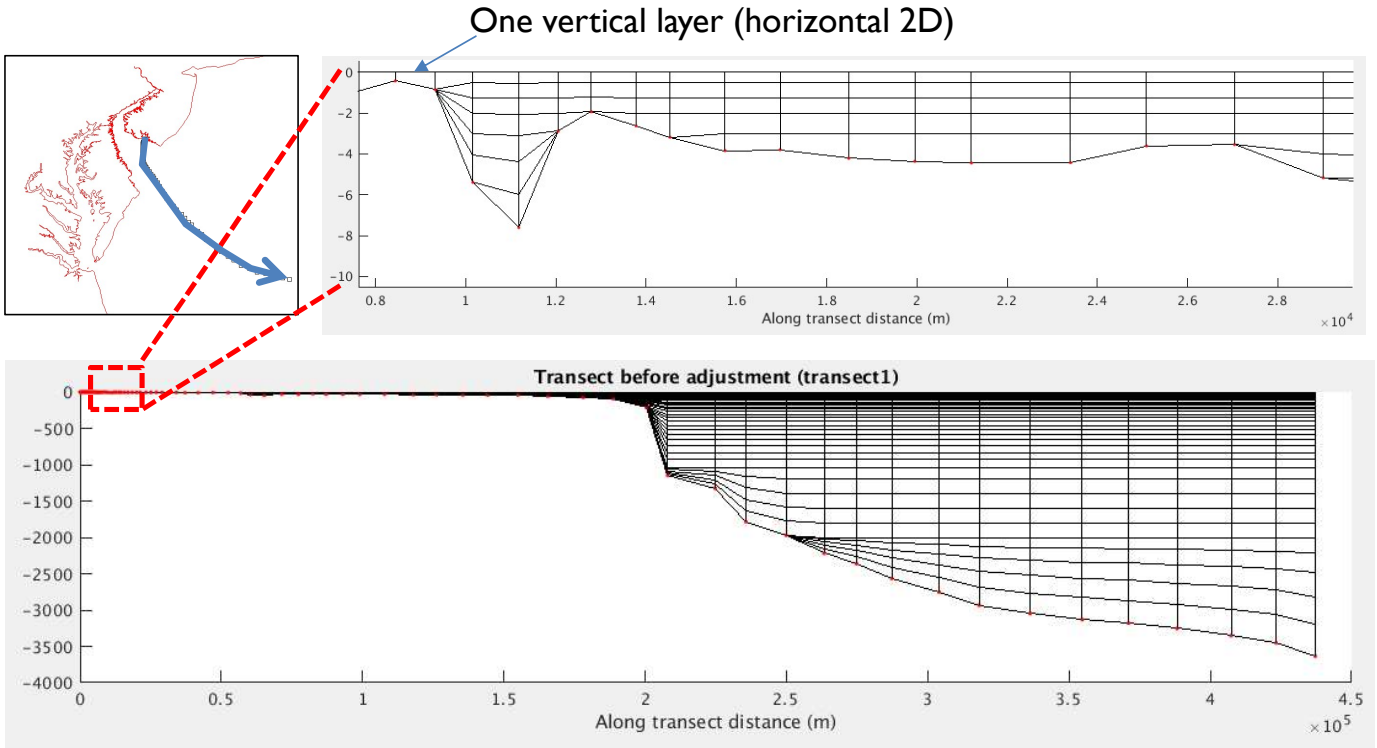
Baroclinic model setup

Terrain following vertical mesh with varying number of layers (LSC^2):

19 levels on average, 1 vertical layer if depth is shallower than 0.5m

Over 30% of the mesh cells are 2D and are dry most of the time

Transect view
(from the shallow areas in the Delaware Bay watershed to the deep ocean)



Ye et al, in press; Ocean Modelling

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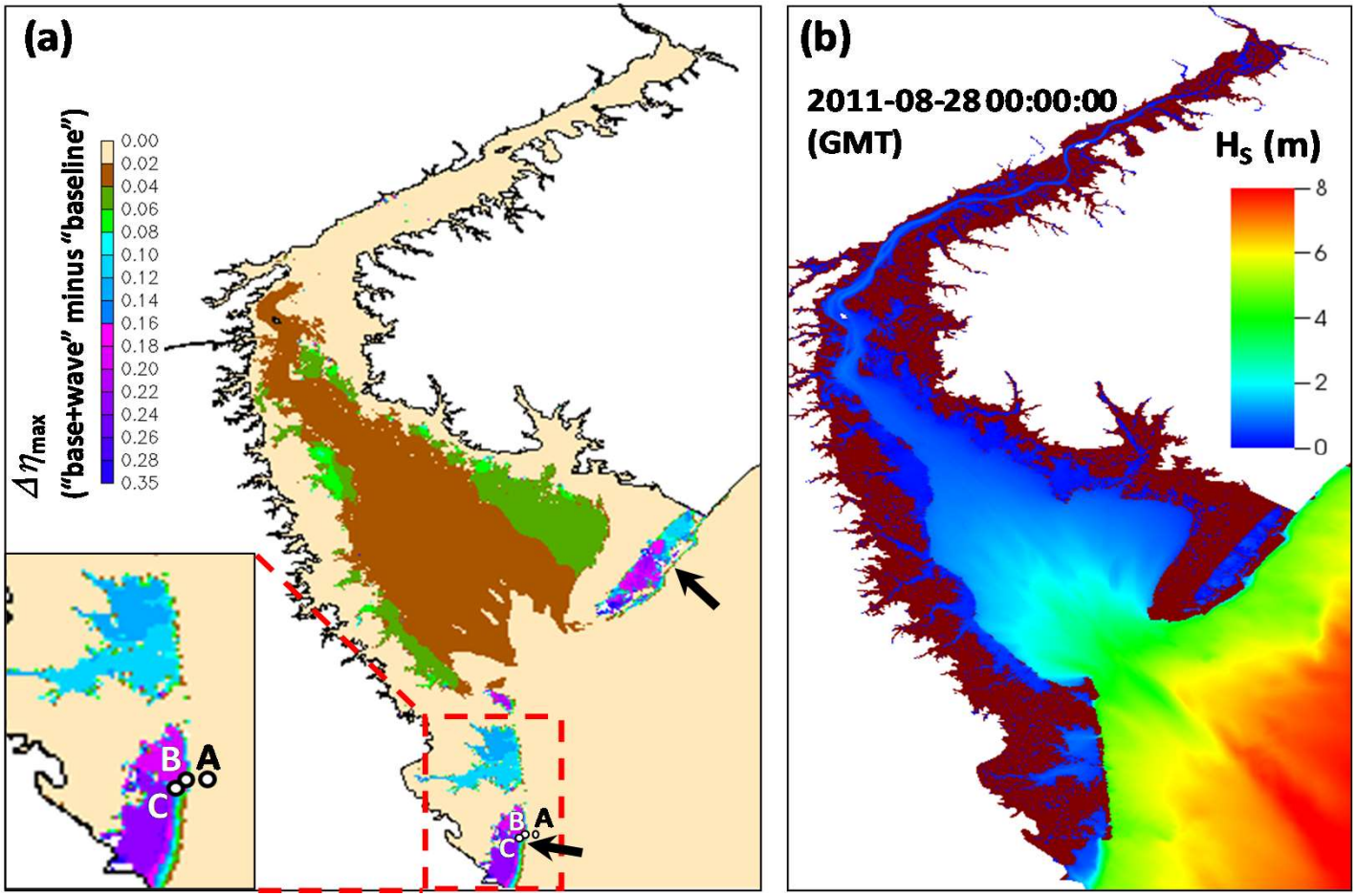
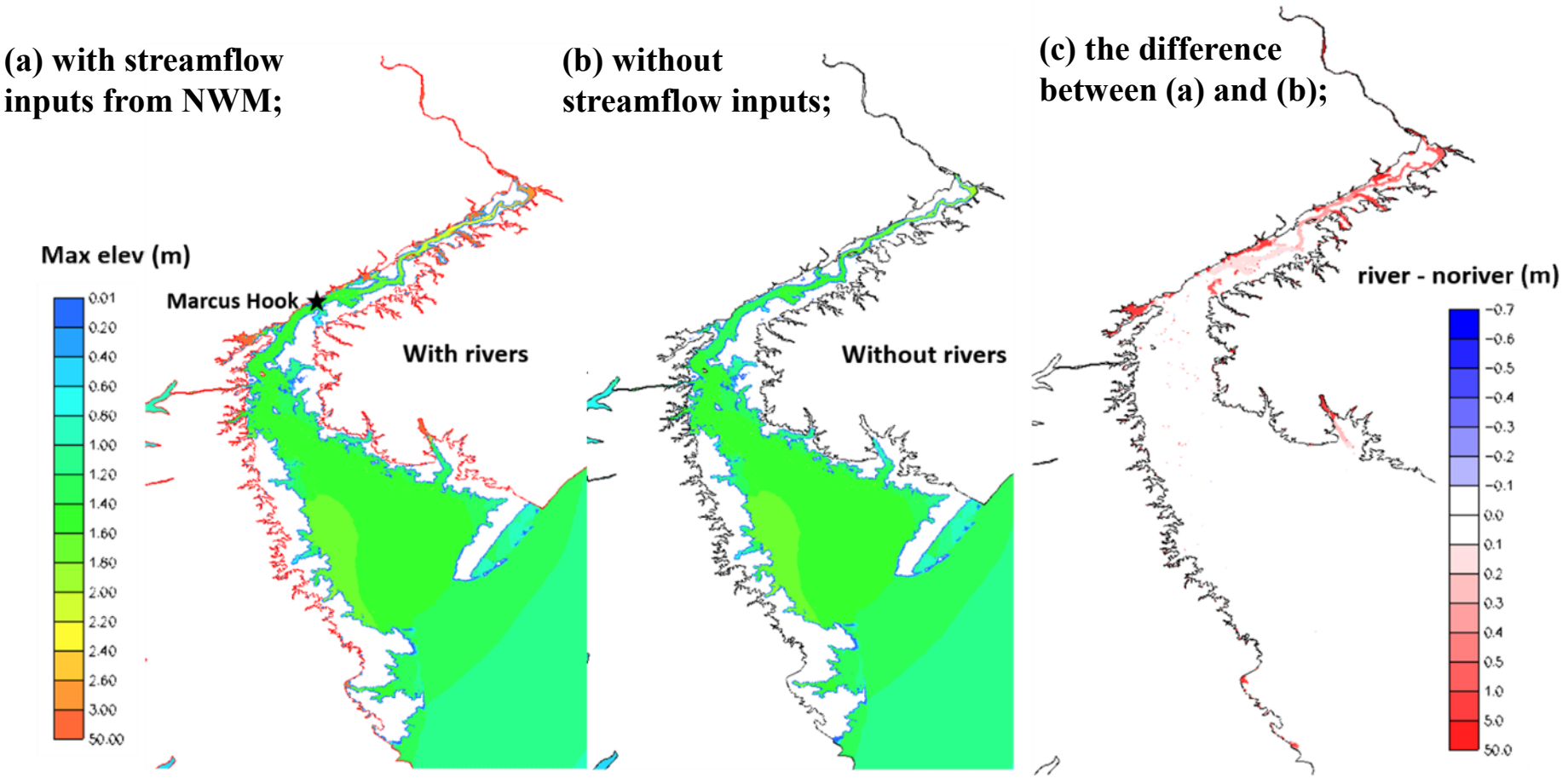
Waves contribution in the maximum elevation (Irene, 2011)



Zhang et al; Submitted; Ocean dynamics

Compound freshwater and coastal flooding effect (Irene, 2011)



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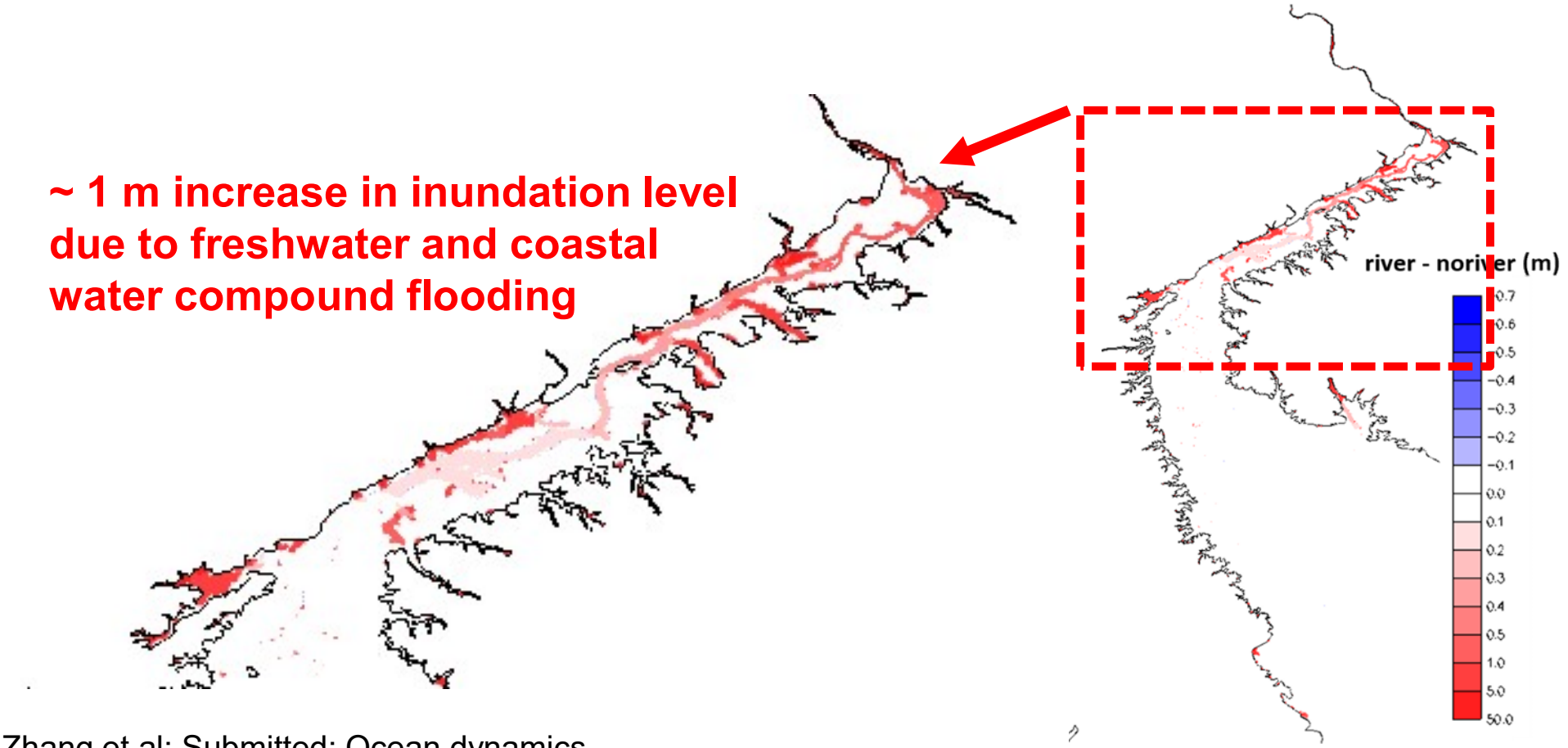

Zhang et al; Submitted; Ocean dynamics

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Future works

- Working with models developers and community to enable NOS' operational models for absorbing inland hydrology variables (i.e. discharges and locally generated run-off)
- ADCIRC
  - Adaptive data driven mesh generation
  - Testing strategies for freshwater variables
  - Updating ADCIRC NUOPC/ESMF interface
- ROMS
  - Testing NUOPC/ESMF model interface in NOAA NEMS environment
  - Implementation of flexible freshwater source terms
  - Considering open-channel type bottom roughness for rivers
- FVCOM
  - Developing NUOPC/ESMF model interface in NOAA NEMS environment
  - Testing flexible freshwater source terms for seamless NWM and FVCOM coupling

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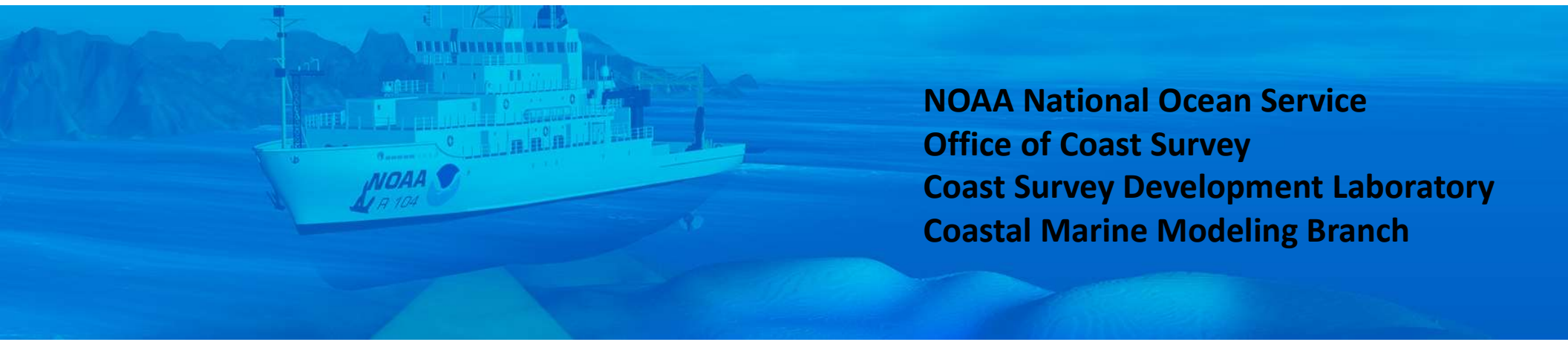
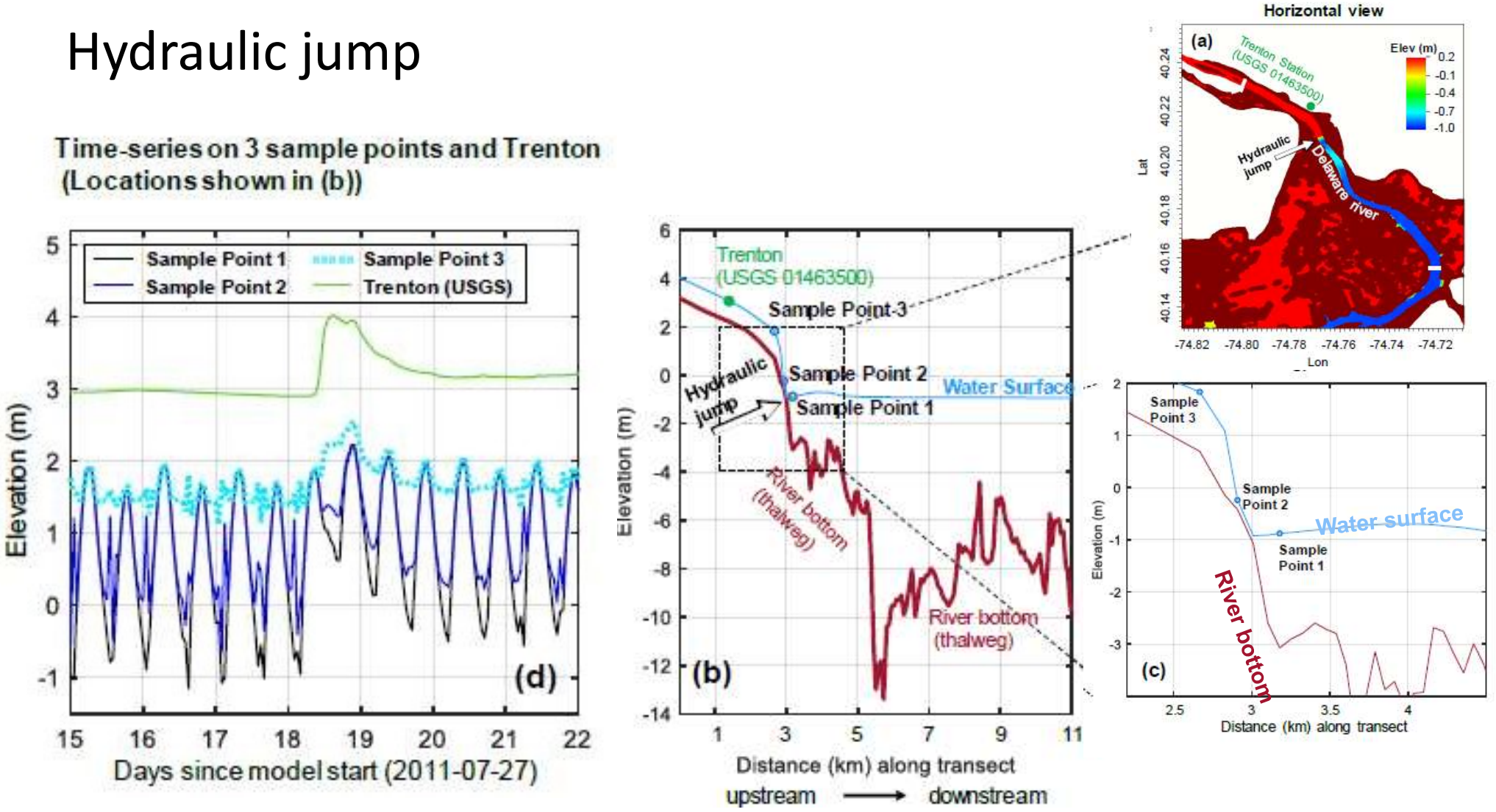
Questions!?

NOAA Office of Coast Survey has been the nation's nautical chart-maker since President Thomas Jefferson requested a hydrographical survey in 1807.



NOAA National Ocean Service
Office of Coast Survey
Coast Survey Development Laboratory
Coastal Marine Modeling Branch

Hydraulic jump



Zhang et al; Submitted; Ocean dynamics